Public Abstract
First Name:Harshani
Middle Name:Ovamini
Last Name:Wijewardane
Adviser's First Name:Carsten
Adviser's Last Name:Ullrich
Co-Adviser's First Name:
Co-Adviser's Last Name:
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Semiconductor devices are used for generating electromagnetic radiation in many everyday applications. Quantum wells, i.e. semiconductor heterostructures are natural candidates for terahertz (THz) sources since the intersubband transitions lie in the THz region. To interpret experimental results and guide further research, one should have a clear understanding of the physical mechanisms governing THz dynamics in quantum wells, especially in the nonlinear regime. The intersubband (ISB) dynamics of conduction electrons in semiconductor quantum wells exhibits a variety of interesting and potentially useful nonlinear phenomena. At the same time, due to its simple (essentially one-dimensional) nature, ISB dynamics serves as an ideal test system to study collective electronic many-body dynamics. In this work we present three different formalisms which we use to describe ISB effects in the nonlinear regime based on the time-dependent density functional theory (TDDFT). We first develop a density-matrix approach based on TDDFT to describe nonlinear ISB conduction electron dynamics in the time domain. We apply this formalism to study coherent control of optical bistability. This method is capable of calculating non-adiabatic or transient effects associated with sudden switching or short pulses. We then focus on the fact that the exact time-dependent exchange-correlation (xc) potential contains information about the previous history of the system, including its initial state. We describe two different formalisms which go beyond the adiabatic approximation and apply them to collective charge-density oscillations in quantum wells. First, we develop a viscosity-based TDDFT in the time domain. A striking consequence of the memory and velocity dependence of the viscosity-based xc potential is that it introduces retardation, which in turn leads to decoherence and energy relaxation. From this formalism, we clarify the dissipation mechanism, and extract ISB relaxation rates. Also, for strong excitations we observe plasmon sidebands. The other formalism is an orbital-based approach, the time-dependent optimized effective potential method (TDOEP). TDOEP has the advantage that it works for both finite and extended systems and yields the correct asymptotic behavior of the xc potential. We solve the full TDOEP integral equation with exact exchange for a quantum well with free and driven plasmon oscillations. We show how the memory arises from the exact exchange and results in retardation effects in the electron dynamics. This work represents the first successful implementation of exact exchange TDDFT in the time domain.